

*Photometric Measurements of Neptune, January to April 1908.* By J. M. Baldwin, M.A., 1851 Exhibition Scholar (Melbourne).

(Communicated by Sir David Gill, K.C.B., F.R.S.)

1. The observations which are recorded in this paper were undertaken chiefly to ascertain whether it were possible to recognise a short-period variation in the brightness of Neptune such as that which Maxwell Hall believed he had found in 1883 and again in 1884.

The first announcement of a variation was made in the *Monthly Notices* (xliv. 257, 1884). The observations made by Mr. Hall were *estimations*, generally in fourths of a magnitude, of the difference between Neptune and a star in the same field, assumed as of magnitude 8.5 (B.D. +15°, 453, mag. 8.5). On the night of 1883 November 29 Neptune seemed to him fainter than on the two preceding evenings, being "as nearly as possible" of the same brightness as the comparison star, but later in the evening Neptune appeared somewhat the brighter. From then till December 14 the estimated magnitude varied between 7.5 and 8.5, but during the nights of December 15, 16, and 18 no variation could be observed. From his observations he deduced a period of 7.92 hours. On December 27 and again on 1884 January 8 Neptune was compared with another star (B.D. 15°, 446, mag. 7.5), but "no variation was noticed on either night, yet Neptune was undoubtedly brighter on January 8 than on December 27" (*Observatory*, vii. 73, 1884).

He observed Neptune again at the next opposition, and in a short note in the *Observatory* (viii. 26, 1885) says: "Careful photometric measures gave November 29<sup>d</sup> 9<sup>h</sup> 44<sup>m</sup> G.M.T. as an epoch of maximum brilliancy, but the variation was only 0.4 magnitude between max. and min. The period of 7<sup>h</sup> 92 observed last year has been fully confirmed." I have unfortunately been unable to find any information as to the observations beyond that contained in this brief paragraph.

2. A considerable number of *measurements* of Neptune with the meridian photometer have been made at Harvard College Observatory,\* almost all by E. C. Pickering,  $\lambda$  Ursæ Minoris

\* *Observatory*, vii. 134, 1884, and viii. 111, 1885; *Harvard Annals*, xxiv. p. 265 and xlvi., part ii., p. 203. In this paper the early comparisons, 4 in number, of Neptune with Uranus, made by Zöllner (*Photometrische Untersuchungen*, p. 150) and the 8 Harvard comparisons with  $\alpha$  Arietis in 1878 (*Harvard Annals*, xl. p. 224) have not been made use of.

being used as standard. The number of observations and results obtained are given in Table I.

TABLE I.

Year.	Observations.	Nights.	Mean Mag.	Mean Error.
1882-83	11	11	7.71	±.11
1883-84	5	5	7.77	±.09
1884-85	9	9	7.63	±.11
1894	5	5	7.71	±.13
1895-96	5	5	7.50	±.10
1896	5	5	7.63	±.02
1897-98	16	10	7.63	±.10

3. The observations of Müller \* at Potsdam are more numerous. These are *measurements* with the Zöllner photometer of the difference in magnitude between Neptune and a suitable comparison star or stars, the same throughout any one opposition. The mean results, etc. for the separate years will be found later on in this paper (Table IV). The mean of all the 138 observations is 7.66 on the scale used in Band viii.; this is exactly the same as the mean of Pickering's 56 observations between 1882 and 1898.

4. In the observations given below, a Zöllner photometer attached to the Steinheil refractor (13.5 cm. aperture and 216 cm. focal length, called photometer D in the *Potsdam Publications*) was used throughout. Two comparison stars were chosen near Neptune, namely B.D. +24°, 1457 and +22°, 1531, the magnitudes given in the Potsdam General Catalogue being respectively 7.97 and 7.18. As usual, four readings were taken for each object, one in each quadrant of the intensity circle (which was always turned in the same sense), the star being respectively to the left of, above, to the right of, below, the artificial star. The complete observation consisted in observing first one comparison star, then Neptune, then the other comparison star. For the next observation the stars were taken in the reverse order, and so on throughout the whole series. The complete results are given in Table II.

\* *A.N.*, 2600, Bd. cix, 121, 1884, or *Observatory*, vii. 264, 1884; *Pots. Publ.*, Bd. viii. It is to be noticed that the magnitudes as given in the *A.N.* are not referred to the same scale as those in the collected results in the *Pots. Publ.*

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TABLE II.

1908.	G.M.T.	Z.D.	M <sub>1</sub> .	M <sub>2</sub> .	Mean.	Reduction.	M <sub>0</sub> .	Phase.	Resi- dual.
Jan. 25	d h m		51.7	7.85	7.98	7.92	+ 01.	7.93	0.68
	7 6		43.5	8.00	7.93	7.97		7.98	- 06.
	9 46		30.4	8.02	7.85	7.94		7.95	- 04.
Feb. 3	10 12		32.5	8.04	7.89	7.96		7.97	0.98
	11 3		37.1	7.80	7.93	7.86	+ 10.	7.87	- 12.
Feb. 9	11 18		41.9	7.96	7.96	7.96	00.	7.96	1.15
	10 7 24		34.0	7.93	7.91	7.92		7.92	1.17
	8 5		31.3	7.88	8.01	7.95		7.95	- 04.
	9 43		32.5	7.97	7.99	7.98		7.98	- 01.
	14 7 22		32.9	7.93	8.06	7.99	00.	7.99	1.27
Feb. 19	8 42		30.5		8.04	8.04	-	8.03	1.38
Mar. 2	9 52		41.9	8.10	8.11	8.11	- 02	8.09	1.63
	10 44		49.3	8.17	8.13	8.15		8.13	+ 14.
	11 10		53.1	8.06	8.02	8.04	- 02	8.02	+ 03.
	16 9 7		43.4	8.23	8.12	8.17	- 03	8.14	1.82
Mar. 16	9 19		45.2	7.91	8.00	7.95	- 03	7.92	- 07.
	22 9 21		48.7	8.01	8.07	8.04	- 04	8.00	1.87
	9 55		53.7	8.08	8.09	8.08		8.04	+ 05.
	24 9 47		53.7	8.14	7.99	8.06		8.02	1.89
	10 16		58.1	8.07	8.07	8.07		8.03	+ 04.
Mar. 24	10 47		62.8	7.99	8.04	8.01		7.97	- 02.
	25 9 2		47.7	8.01	8.02	8.01		7.97	- 02.
	10 25		60.1	8.05	7.98	8.01		7.97	- 02.
	10 48		63.6	8.09	8.06	8.07	- 04	8.03	1.89
	26 9 0		48.0	8.02	8.02	8.02	- 05	7.97	1.90
Mar. 26	10 21		60.1	7.94	8.03	7.99		7.94	- 05.
	10 48		64.2	8.00	8.10	8.05		8.00	+ 01.
	27 8 31		44.6	7.95	8.03	7.99		7.94	- 05.
	9 19		51.3	8.09	8.07	8.08	- 05	8.03	1.90
Apr. 26	8 28		61.3	8.22	8.06	8.14	- 08	8.06	1.76
Apr. 28	7 39		54.9	7.98	8.00	7.99		7.91	- 08.
	8 19		61.0	8.15	8.07	8.11	- 08	8.03	+ 04.
					Mean	7.990		± 0.059	

Jan. 25. Slightly foggy.

Feb. 14. Hazy, but no clouds visible in bright moonlight.

Feb. 19. Clouded over, weight  $\frac{1}{2}$ .

Mar. 2. Not very clear, hazy near horizon.

Mar. 16. Sky bad, and so observations not reliable, weight  $\frac{1}{2}$ .

Apr. 26. Cloud slowly rising, but observations probably good.

In this table the first two columns give the date and G.M.T. of observation, and the corresponding zenith distance of Neptune, the next columns the observed magnitudes (corrected for atmospheric absorption) referred to the brighter and fainter comparison stars respectively, and the mean. Each observation gave the difference in magnitude between the comparison stars; from the whole series the mean was 0.83 mag., and so the values for the comparison stars are taken as 7.16 and 7.99 respectively. In the sixth and seventh columns are given the correction to mean opposition and the magnitude in mean opposition. The eighth column gives the phase angle; this remains always so small that it is not to be expected that any variation of magnitude with phase angle can be recognised with certainty. The last column gives the difference, observed mag. – mean magnitude.

A glance at the column of residuals shows that the agreement between the observations is extremely satisfactory, the mean error of one observation, giving a weight  $\frac{1}{2}$  to certain observations as indicated, being only  $\pm 0.59$  mag.

5. Amongst the foregoing material there are three series of observations which are especially suited to detect a short period variation in brightness such as that announced by Hall, the epoch and amplitude of which, owing to movement of the markings supposed to give rise to the variation, may be gradually changing.

(1) Müller's 72 observations on 37 evenings between 1884 Aug. 24 and 1885 March 10.

(2) Pickering's 16 observations on 10 evenings between 1897 Dec. 11 and 1898 March 3.

(3) The above 32 observations on 15 evenings.

If these observations be examined it will be at once evident that they show no trace of a short-period variation, the residuals being just such as occur in photometric work. However, as a direct test, the series have been taken separately, the phase computed for a period 7.92 hours and an arbitrary epoch, and the light curve plotted. In the case of Müller's longer series, this has been done also for parts of the series. The result is in every case the same; the observations furnish no evidence whatever of a variation of period 7.92 hours. In particular, Müller's observations from 1885 Jan. 8 to Feb. 24 and those given in this paper are especially conclusive on this point, as the observations are well distributed over the curve. With regard to his observations from 1884 Aug. 24 to 1885 March 10, Müller says (*Pots. Publ.*, viii. p. 352), "during the whole period of nearly 7 months not the slightest trace of a periodic variation in light can be recognised. The magnitude in mean opposition varies between 7.39 and 7.81, and such a difference can be very well explained by uncertainty in the measurements if the fact that these extreme values were obtained when the planet was very low, and under unfavourable conditions, be taken into account"; and a little further on, "the observations of the following years also, although not nearly so numerous, are in direct opposition to the hypothesis of a periodic variation in the light from Neptune."

This latter remark may be extended to the whole of the photometric observations of Neptune.

6. Looking now at the evidence which Hall gave as showing a periodic variation of brightness, it consists of—

(1) A series of 25 estimations of difference of magnitude.

(2) Some photometric observations, of which particulars are not available.

If the first set of observations be plotted to obtain the light curve, it will be found that the assumption of variation practically rests on 3 observations, for, apart from these, no residual occurs which could not be explained by the method of observing, the greatest being 0.3 mag. from a mean 7.8. Of these three, two are the early observations of Nov. 29 (mag. 8.5) and Dec. 1 (mag. 8.3), and it was not until after the first observation that a diagonal prism was used to alter the relative positions of Neptune and the comparison star; and the third, on Dec. 7 (mag. 8.3), requires in any case a correction of more than -0.4 to bring it on to a curve through the other observations.

From the second set a variation of 0.4 mag., occurring about 1885 Nov. 29, was deduced. In the absence of details it is impossible to say what instrument was used, how many observations were made, or over what period they extend. Against the hypothesis of variation, however, there is very conclusive evidence in Müller's observations before and after this epoch, for there are continuous observations from Oct. 23 to Nov. 19, and again from Jan. 8 to Feb. 24, which effectively include any assumption of variation during these periods, and observations on Dec. 1, 2, and 16, which give no evidence in favour of it.

It would appear, then, in the highest degree probable that the "variation" announced is due to errors of observation, especially when account is taken of the small amplitude deduced.

7. The mean value of the brightness of Neptune in mean opposition, as determined by the present series of observations, is 7.99, the mean error of one observation being  $\pm 0.59$ , the system to which the magnitude is referred being that of the Potsdam *Durchmusterung*.

The comparison stars used by Müller, the magnitude on the system of his Potsdam planetary observations, and the magnitude from the Potsdam General Catalogue are given in Table III.

TABLE III.

Comparison Star.	B.D.	Mag.	Mag. P.G.C.	Reduction.
52	+13°, 411	7.25	7.52	+.27
43	+15°, 430	6.29	6.68	+.39
34	- 4°, 4376	5.41	5.54	+.13
49	+16°, 458	6.95	7.34	+.39
56*	+16°, 432	7.96	8.23	+.27

\* Owing to a clerical error, this comparison star has been printed as 55 instead of 56 throughout the observations of Neptune, and the discussion of the result of these in vol. viii. of the *Potsdam Publications*. Beyond writing 56 for 55 no change requires to be made.

Stars 34 and 56 are not contained in the General Catalogue, but from *Pots. Publ.*, Band viii. p. 233,

$34 - \beta$  Herculis is 2.53 mag.  
and  $56 - \sigma$  Arietis is 2.51 mag.

Also from the General Catalogue,

$\beta$  Herculis is 3.01 mag.  
and  $\sigma$  Arietis is 5.72 mag.,

and hence the magnitudes given in Table III are obtained.

Next, combining these results with the table given on p. 354 of Müller's paper we get Table IV.

TABLE IV.

Year.	Number of Observations.	Mag.	Prob. error of one Observation.	Comparison Star.	Reduction.	Reduced Magnitude.
1878	11	7.70	$\pm 0.051$	52	+.27	7.97
1881-2	17	7.75	.071	52	+.27	8.02
1883	6	7.75	.095	43	+.39	8.14
1883	7	7.70	.085	34	+.13	7.83
1884-5	72	7.62	.056	49 and 56	+.33	7.95
1885-6	15	7.69	.074	49 and 56	+.33	8.02
1886-7	7	7.62	.045	49 and 56	+.33	7.95

The mean magnitude on the system of the Potsdam *Durchmusterung* is thus 7.97.

For the comparison with Pickering's observations, the difference Potsdam - Pickering is given on p. 34, of the introduction to the Potsdam General Catalogue, as follows:—

Magnitude.	W	GW
7.50-7.99	+0.36	+0.29
8.00-8.49	+0.37	+0.30

If the colour of Neptune be assumed as between W and GW the reduction +0.34 cannot be far from the truth, and this gives 8.00 as the reduced value of Pickering's mean result.

It is seen, then, that the results of the present series are in very close agreement with the previous observations of Müller and Pickering.

8. The results arrived at from the present series of observations in conjunction with previous observations of Neptune may be summarised as follows:—

(1) The variations of the estimated brightness of Neptune announced by Hall are probably due to errors of observation, as the measurements of other observers about the same time, and also

at other oppositions, give not the slightest trace of any such variation. Consequently the time of rotation of 7.92 hours deduced by him must be regarded as unsupported by observation.

(2) The observed magnitude of Neptune in mean opposition is 7.99 on the system of the Potsdam *Durchmusterung*, showing, in extremely satisfactory agreement with Müller's value 7.97, and Pickering's value 8.00.

In conclusion, I wish to record my thanks to Professor Müller, at whose suggestion these observations were made, for the interest which he has shown throughout this work.

*Astrophysical Observatory, Potsdam :*  
1908 June 6.

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*Observations of helium D<sub>3</sub> absorption in the neighbourhood of Sun-spots in 1907.* By Captain R. A. C. Daunt, D.S.O.

The following observations of D<sub>3</sub> absorption in the neighbourhood of sun-spots were made with a 3-inch equatorial refractor and a large Thorp, prism-grating spectroscope, 15,000 lines to the inch, the eyepiece ordinarily employed being a Steinheil monocentric 20 m/m power 52. The identification of the several groups according to the Greenwich numeration will, it is hoped, be of service for comparison with spectro-heliographic and cognate studies of the same groups. In Table I. the numbers of the various groups and the dates on which they were observed are given, as well as the type or phase in the life-history of the groups at the times of observation, according to the classification of Father Cortie in his paper "On the Types of Sun-spot Disturbances," *Astrophysical Journal*, xiii., 4th May 1901.

In all the cases of absorption of D<sub>3</sub> observed, the dark line was never seen over the umbræ or penumbræ of the spots of any group, but between the spots, or on the photosphere in their neighbourhood. It would appear that some of these groups showed D<sub>3</sub> in absorption on certain days only, and not on others. This may be real; but as the appearance of D<sub>3</sub> is very intermittent, it is more likely to be due to the hour of observation; and had I been able to keep the groups under observation throughout the day, D<sub>3</sub> would probably have been seen near the spots some time or other of the day during the apparition, provided the groups remained active and agitated.

In Table II. are given the Greenwich numbers of those groups in the neighbourhood of which D<sub>3</sub> was not observed. For the reason stated above, some of these groups may have shown the absorption effect of D<sub>3</sub> at some time, but it was not observed.

As, however, most of these spots were small, or of a regular and quiescent nature, it is perhaps unlikely that D<sub>3</sub> was reversed.

A table follows showing the proportion of the total number of fresh groups observed each month with those that showed D<sub>3</sub>.